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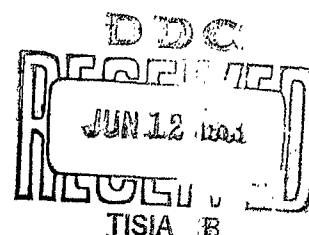
Report No. 8926-164

Material - Aluminum - 7075-T6

Evaluation of Impressed Electromotive Force Cathodic
Protection

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28 August 1957



Published and Distributed
under
Contract AF33(657)-8926

CATALOGED BY DDC
AS AD NO. 407738

407 738

Post Office Box 1950, San Diego 12, California 296-6611

Material Post Office Box 2071 273-8000 | Accounting Post Office Box 510



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Abstract:

Electromotive couples consisting of 0.064" x 24" x 24" bare 7075-T6 aluminum cathodes and 0.064" x 2" x 3" RC-70 titanium (commercially pure) or equivalent platinum cathodes were separated from each other by a 0.065" x 8" dia. neoprene insulator, connected together with copper wire and immersed in sea water. In order to nullify the "natural" galvanic current, a regulated direct current was introduced into the copper portion of the circuit in such a manner that it opposed the galvanic current. In a series of tests wherein the impressed voltage and current was varied from specimen to specimen for periods ranging 2 to 16 days, the impressed currents failed to prevent corrosion of the 7075-T6 aluminum alloy. This was attributed to the formation of hydroxyl ions at the aluminum alloy cathode. These ions were believed corrosive to the aluminum alloy.

Reference: Hooper, A. F., Sutherland, W. M., "Cathodic Protection of Submerged Metals in Sea Water," General Dynamics/Convair Report MP 56-227, San Diego, California, 28 August 1957. (Reference attached).

ANALYSIS

PREPARED BY: Hooper/George

CHECKED BY W. M. Sutherland

REVISED BY

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SAN DIEGO

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REPORT NO. 56-227
CATHODIC PROTECTION OF SUBMERGED
METALS IN SEA WATER

INTRODUCTION:

Corrosion caused in the presence of an electrolyte such as sea water is considered to be electrochemical in nature. Electrochemical corrosion involves chemical reactions and an interchange of electrons (current flow), between the corroding medium and two or more heterogeneous areas. When metal is immersed in an electrolyte a solution potential occurs at the electrolyte-metal interface. The driving force or difference in solution potential between two heterogeneous areas will cause a flow from the area of high solution potential (anode) to the area of low solution potential (cathode). The amount of metal loss at the anode is a function of the total quantity of electrons transferred or total current flow.

An electrochemical corrosion reaction is dependent on a continuous flow of electrons through two branches of the electrical circuit, the electronic path through the metal and the electrolytic branch due to the migration of the ions through the electrolyte. To stifle the corrosive action, it is necessary either to prevent the anode or cathode reaction or to intercept the flow of electrons in either branch of the corrosion cycle. The electrolytic branch of the circuit can be interrupted by the application of an organic coating, thus isolating the metal from the electrolyte. This method of corrosion prevention necessitates a continuous film and any voids in the coating result in localized corrosion of the underlying substrate.

The other method of corrosion prevention involves impressing a potential on the metal from some external source, which renders the metal surface sufficiently negative, so that the positively charged ions will not be released from the metallic lattice.

The external EMF may be supplied by a sacrificial anode, battery or rectifier. The use of a sacrificial anode for cathodic protection of an airframe is doubtful, because of the excessive weight necessary for a successful system. This test was initiated to study the feasibility of the application of an external EMF supplied by a battery or rectifier for cathodic protection of an airframe.

ANALYSIS

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OBJECT:

To investigate the use of an impressed electromotive force for the cathodic protection of 7075-T6 aluminum alloy panels immersed in sea water.

CONCLUSIONS:

1. The use of an impressed electromotive force for the cathodic protection of bare 7075-T6 aluminum alloy panels immersed in sea water was not successful.
2. The probable cause for the impressed electromotive force not being successful was the formation of hydroxyl ions, produced in the electrochemical reaction, at the aluminum alloy cathode.

TEST SPECIMENS AND PROCEDURE:

The test specimens were .064 x 24 x 24 inch bare 7075-T6 aluminum alloy panels with a .0625 x 8 inch diameter circular sheet of neoprene rubber cemented in the center of the panel. The rubber neoprene sheet was used to increase the current distribution over the immersed portion of the bare 7075-T6 aluminum alloy cathode. The .064 x 2 x 3 inch anode of RC-70 titanium or platinum was mounted in the center of the neoprene sheet and was insulated from direct metal contact with the cathode by sealing all contact points with EC-1291, a thiokol rubber compound, manufactured by Minnesota Mining and Manufacturing Company. Photographs of a typical specimen are shown in Figures 1 and 2.

Cathodic protection was attempted by the application of an impressed EMF on a bare 7075-T6 aluminum alloy cathode, combined with an anode of RC-70 titanium or platinum. Both the platinum and the RC-70 titanium metals are cathodic to bare 7075-T6 aluminum alloy metal, but in this test the EMF was applied to reverse the polarity of these couples. The initial tests were conducted with an anode of RC-70 titanium, because of its known resistance to sea water corrosion, while awaiting delivery on the platinum anodes. The platinum anodes were fabricated by Charles Engelhard, Inc., 850 Passaic Avenue, East Newark, New Jersey. The electrical leads for the impressed EMF's were connected to the specimen, which was mounted on a non-conductive bracket as shown in Figures 1 and 2. The specimen was then immersed in a concrete tank containing circulating sea water at Scripps Institute of Oceanography in LaJolla, California. The immersed portion of the specimen was approximately 15 x 24 inches leaving an area of 9 x 24 inches above the waterline to simulate a waterline condition on a hull bottom of an airframe. Each specimen was inspected after an interval of 24 hours immersion. Each specimen was again inspected at varying intervals during the immersion period. A diagram of the EMF system is shown in Figure 3.

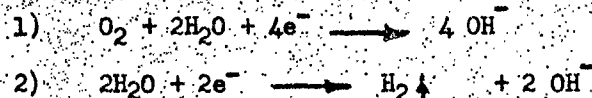
TEST SPECIMENS AND PROCEDURE: (Continued)

The control specimen was a .064 x 24 x 24 inch bare 7075-T6 aluminum alloy panel having no metallic couple or impressed EMF. Both the control and the specimen with the impressed EMF received no surface treatment or finish system.

RESULTS AND DISCUSSION:

Several tests were conducted using the impressed EMF's listed in Table I, with corrosion resulting on the bare 7075-T6 aluminum alloy cathodes. The corrosion present on these bare 7075-T6 aluminum alloy cathodes, on which cathodic protection was attempted, was similar to that on the bare 7075-T6 aluminum alloy control specimens. The corrosive condition of these specimens was as follows: severely corroded at the waterline and moderately corroded on the immersed portion in straight lines parallel to the grain direction. These corroded areas were anodic to the surroundings surface due to one or more possible environmental conditions and/or heterogeneity of the metal surface.

The problem of cathodically protecting an aluminum alloy was anticipated to be difficult due to the chemical affinities of aluminum. One of the electrochemical reaction products of cathodic protection is the hydroxyl ion, which chemically attacks aluminum. The hydroxyl ion is produced at the aluminum alloy cathode - electrolyte interface by one of the two following reactions:



The amount of hydroxyl ions produced is a function of the current flowing in the system, and increasing the applied EMF would only result in a higher concentration of the hydroxyl ion at the aluminum alloy cathode.

The solution potential of an aluminum alloy in an electrolyte is relatively constant, when the pH of the electrolyte is between 5 and 9. When the pH of the electrolyte is lower than 5 and higher than 9 the solution potential of an aluminum alloy rapidly increases to a higher potential, thus making the metal surface more susceptible to corrosive attack. External voltages in excess of 1 volt readily produce hydroxyl ions and increase the pH of the electrolyte adjacent to the aluminum alloy surface, thus preventing any protective measures of the system. If the formation of the hydroxyl ions could be decreased at the aluminum alloy cathode, it is believed that protection could be achieved with an impressed EMF System of this type.

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RESULTS AND DISCUSSION: (Continued)

In a test conducted using a sacrificial anode of commercially pure zinc in combination with a 7075-T6 aluminum alloy cathode in sea water, protection was successful during a 10 day immersion test. The electrochemical reaction product at the aluminum alloy cathode again is the hydroxyl ion, but it is believed to react with the zinc ion released at the zinc anode to form a complexed zincate ion $[\text{Zn}(\text{OH})_4]^-$. Therefore, the hydroxyl ion concentration is not high enough to interfere with the protective qualities of the system. This sacrificial anode system could be further evaluated by test to determine the limitations for use on water based airframes.

NOTE: The data from which this report was prepared are recorded in Engineering Test Laboratories Data Book No. 971.

TABLE I

THE IMPRESSED EMF APPLIED ON SPECIMENS

Specimen No.	Voltage Applied (Volts)	Current (Amps)	Total Days Tested
1	.05	.0004	15
2	.1	.0009	6
3	.3	.001	2
4	.375	.001	3
5	.6	.0015	4
6	.6	.0015	7
7	.76	.002	4
8	1.0	.001	2
9	1.0	.001	3
10	1.2	.002	2
11	1.5	.002	3
12	1.6	.003	6
13	1.8	.003	6
14	2.0	.004	4
15	2.5	.006	5
16	2.5	.006	8
17	3.5	.035	4

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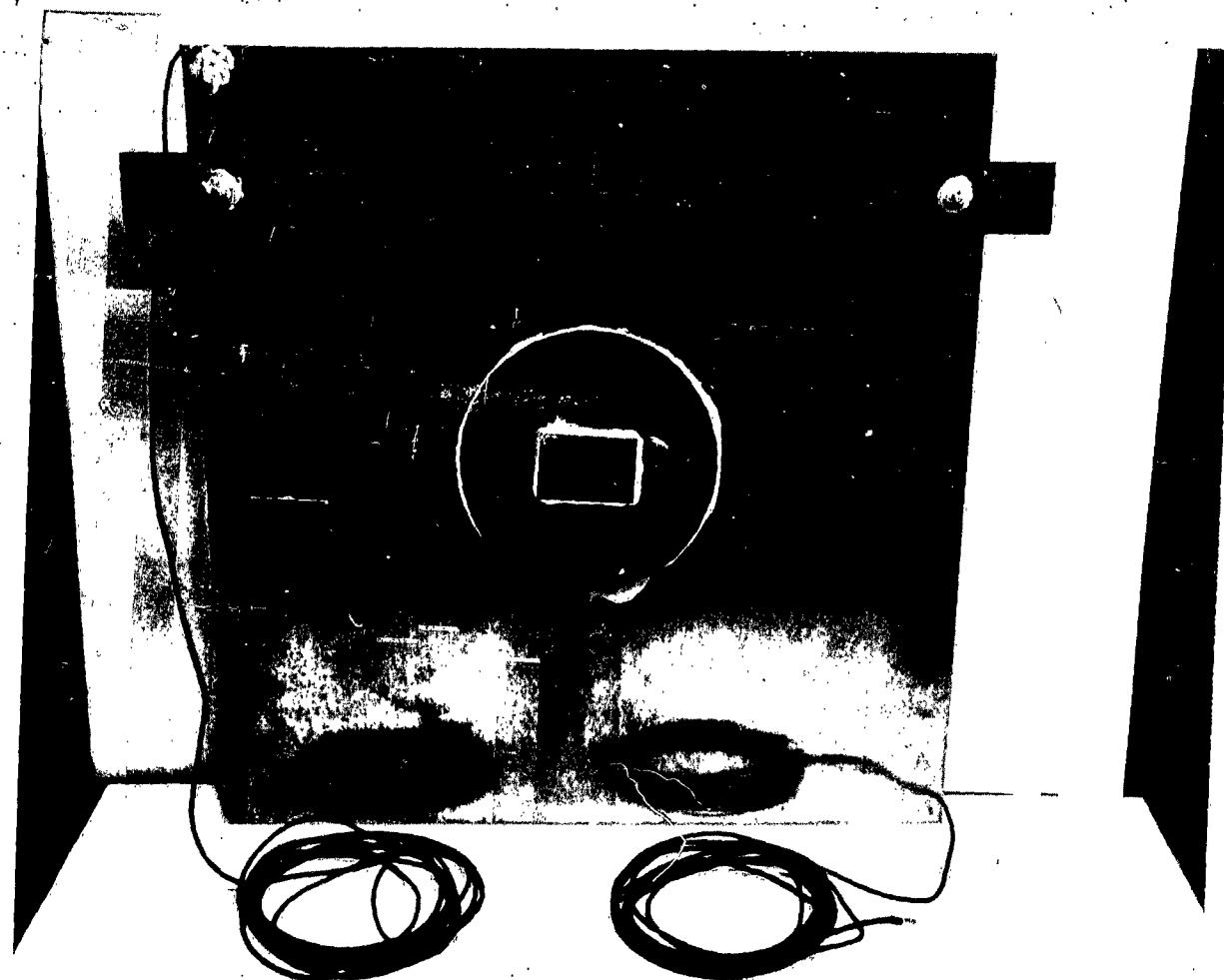


FIGURE I
FRONT SIDE OF THE IMPRESSED EMF SPECIMEN

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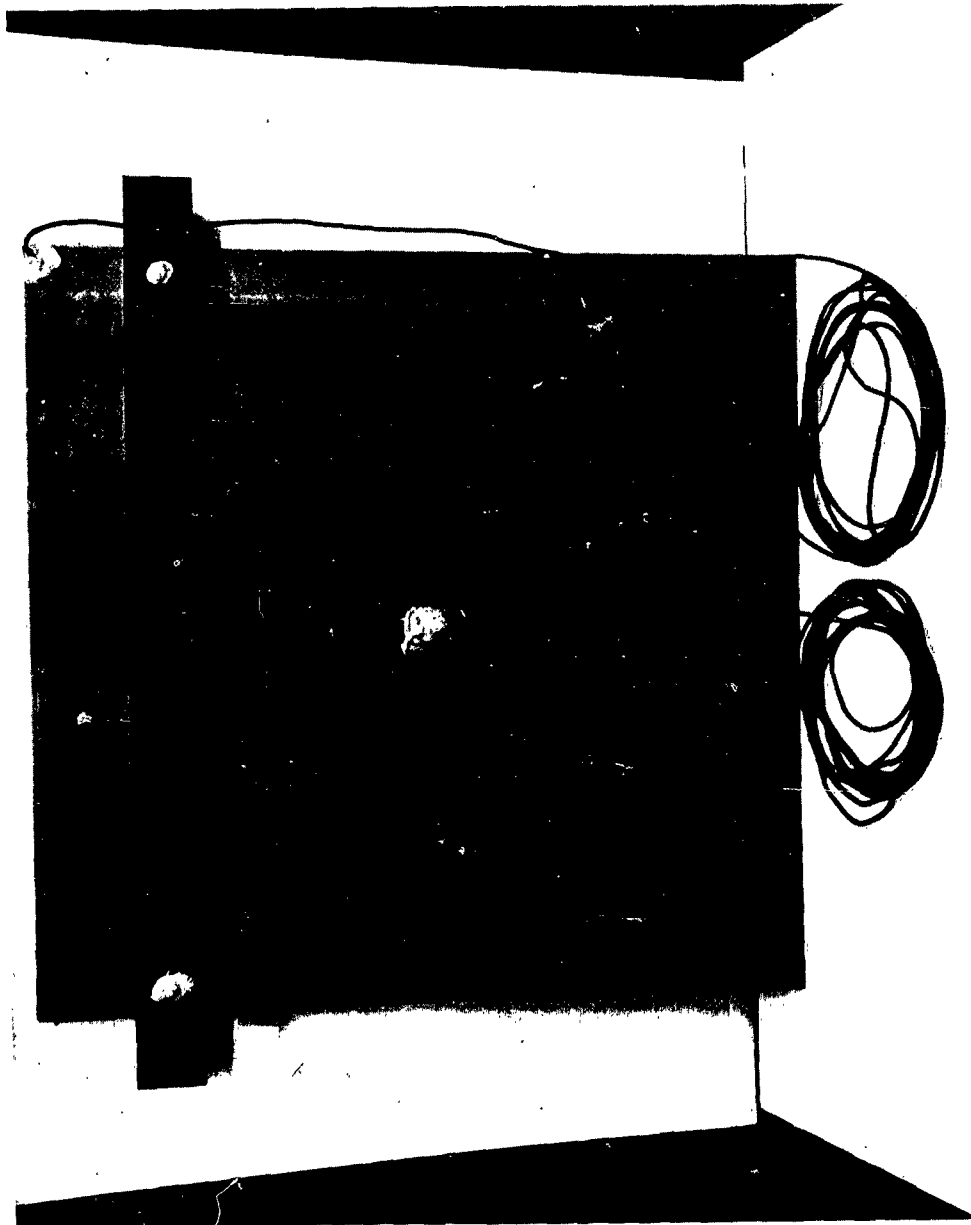


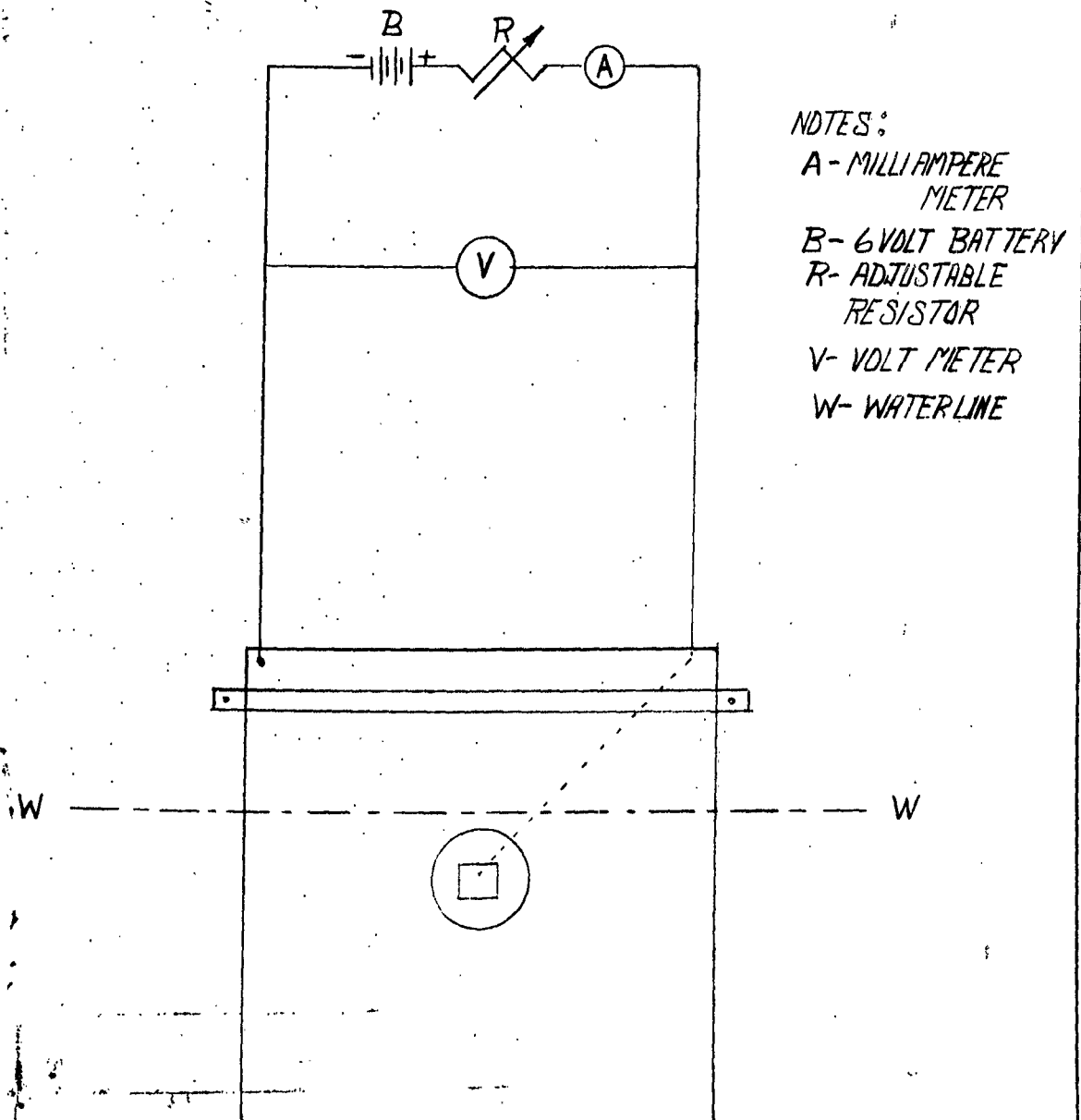
FIGURE II
REVERSE SIDE OF THE IMPRESSED EMT SPECIMEN

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DIAGRAM OF EMF SYSTEM



NOTES:

A - MILLIAMPERE
METER

B - 6 VOLT BATTERY
R - ADJUSTABLE
RESISTOR

V - VOLT METER

W - WATERLINE

FIGURE 3